N O T I C E

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COMMISSION OF THE EUROPEAN COMMUNITIES
JOINT RESEARCH CENTRE
ISPRA ESTABLISHMENT (ITALY)

HCMM SATELLITE FOLLOW-ON INVESTIGATION No. 25
SOIL MOISTURE AND HEAT BUDGET EVALUATION IN SELECTED EUROPEAN ZONES OF AGRICULTURAL AND ENVIRONMENTAL INTEREST
(TELLUS PROJECT)

(E81-10057) HCMM SATELLITE FOLLOW-ON INVESTIGATION NO. 25. SOIL MOISTURE AND HEAT BUDGET EVALUTION IN SELECTED EUROPEAN ZONES OF AGRICULTURAL AND ENVIRONMENTAL INTEREST (TELLUS PROJECT) (Joint Research Centre of G3/43 N81-13414 Unclas 00057

Third Progress Report

April 31st - August 31st, 1980

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SUMMARY.

The TELLUS Project entered its central application phase.

A simple procedure to evaluate actual evaporation was derived by linearizing the surface energy balance equation, using Taylor's expansion. The original multi-dimensional hyper-surface could be reduced to a linear relationship between evaporation and surface temperature or to a surface relationship involving evaporation, surface temperature and albedo. This procedure permits a rapid sensivity analysis of the surface energy balance equation as well as a speedy mapping of evaporation from remotely sensed surface temperatures and albedo. Comparison with experimental data yielded promising results.

Testing the validity of evapotranspiration and soil moisture models (as TERGRA) in semi-arid conditions is one of the aims of the TELLUS Project. It corresponds with the Commission's initiatives in favour of the Associated Developing Countries. In particular it can be viewed as an initial contribution to the solution of menacing desertification problems. Wheat was the crop chosen for a continuous measurement campaign made in the South of Italy. Radiometric, micrometeorologic, agronomic- and-soil data were collected and centralized at JRC for processing and interpretation.

A number of studies on the relations between HCMM sensed surface temperatures and different land-use pattern as well as local topography were performed.

HCMM night digital data recorded over Belgium and corresponding LANDSAT data were analyzed. Forested areas in the Ardennes could be well delineated by their high surface temperatures. From an HCMM scene of the Upper Rhine Valley between Basel and Frankfurt it was confirmed that HCMM's resolution is not sufficient to determine the boundaries of various geographic units smaller than 600 m or to establish the exact limits of such topographic structures.
On the contrary, HCMM thermal images were found to be much more comprehensive for studies on a regional scale and thermal patterns at this scale can be related to and explained by topographic structure. HCMM's surface temperatures appear to be well correlated with forest distribution. Forests on steep slopes or convex terrain show very high temperatures (as warm as city centers). Contrast between forested and unforested terrain is the most essential factor of the distribution of warm and cold surfaces. Many factors seem to influence the distinctive behaviour of forested surfaces (presence, inversion or interruption of boundary layers, sensible heat flux between air and forest being higher than adjoining grassland and arable lands, etc.). Presence of cold air reservoirs and cold air streams was also explained for different situations.

Mesoscale heat budgets particularly affected by anthropogenic heat release were examined. This investigation was performed on a segment of an HCMM scene encompassing the Upper Rhine Valley between Basel and Frankfurt and the surrounding highlands. The influence of urban settlements of various sizes was interpreted as well as the presence of industrial complexes which were identified and analyzed in detail.

A further calibration of the HCM radiometer was attempted using water temperatures of Lake Geneva and the radiation balance of a pine forest. These attempts cover the period of May-November 1978 and a temperature range from 9-23°C.

From their results one may tentatively conclude that the HCMR underestimated true surface temperature by about 5°C. Additional calibration studies are needed to reach a more definite conclusion.

The RADTRA model for atmospheric corrections was employed extensively in the calibration study. The model had been modified by the insertion of a correct value of the mass absorption coefficient K_2, but considerable difficulties were encountered with the model.
These problems were communicated to the HCMM Project Scientist and the model has been reprogrammed since.

Some of the above-mentioned activity, already accomplished by the authors, is described in the annexed documents forming part in extenso of this report (see list at page 39).

1. INTRODUCTION

TELLUS is a remote sensing project centered around the satellite EXPLORER-A, bearing the sensors HCMM (Heat Capacity Mapping Mission). The special feature of this satellite measuring the temperature cycling (N/D) of objects on the Earth surface makes it suitable for hydrological and/or geological prospection.

The main objective of TELLUS is to demonstrate that such temperature cycling, or diurnal temperature only, can be related to moisture content in bare and vegetation-covered soils and to anthropogenic heat release. The study of the influence of natural modifications on the regional heat budget is another important subject of investigation.

The objectives of the proposed programme, while partially fulfilling a number of specific needs in the policy of agriculture and the environment, towards European and Associated African Countries, also correspond to the specific research objectives of the participating Institutes.

The role of the JRC in the TELLUS project consists of two distinct parts:

- A coordinating activity for the contribution from national institutes (co-investigators) working on different test sites and topics (see the 1st Progress Report). This coordination includes the present liaison with NASA, Space Goddard Flight Center. (GSFC).
- An experimental activity, essential in itself, on test site No.1, and organization and participation in Joint Flight Campaigns. In addition the JRC is dispatching, processing and interpreting data received from NASA/GSFC and ESA/EARTHNET, Centre de Météorologie Spatial de Lannion.

2. TELLUS FRAMEWORK

The main lines of TELLUS' organization and objectives are here recalled. This will help to better understand who did, why and where during the reporting period. For a more detailed information please look it up in the 1st Progress Report (Chapt.s 2,3 and 4) and in ref [1] and [2].

TABLE I: LIST OF ORGANIZATIONS AND INSTITUTES PARTICIPATING IN THE TELLUS PROJECT (HCM-025)

TEST-SITE COORDINATORS (TSC'S)	CO-INVESTIGATORS (COI'S)	ORGANIZATIONS AND INSTITUTES	ABBREVIATION
		DIRECTORATES OF THE EUROPEAN COMMUNITIES	
		- Directorate-General for Agriculture, Brussels	DG-VI
		- Directorate-General for Research, Science and Education, Brussels	DG-XII
		- Joint Research Centre, Ispra	JRC
		- EC Delegation, Washington	DG-I/WD
		NATIONAL ORGANIZATIONS AND INSTITUTES	
Feddes R.A.		Belgium	
	D'Hoore J.M.	- Fakulteit der Landbouwwetenschappen, Katholieke Universiteit, Leuven	KUL/LBB
		Denmark	
	Eckardt F.E.	- Institutet for Okologisk Botanik, University of Copenhagen	UK/IOB
Goillot Ch.		France	
	Goillot Ch.	- Service de Télédétection, INRA Versailles	INRA/ST
	Barloy E.	- Station d'Amelioration des Plantes, INRA Rennes	INRA/SAP
	Seguin B.	- Station de Bioclimatologie, INRA Montfavet	INRA/CRASE/SB
	Perrier A.	- Station de Bioclimatologie, INRA Versailles	INRA/SB
	Becker F.	- Groupe de Recherches en Télédétection Radiométrique, Université de Strasbourg	ULP/GRTR
Gossmann H.		Germany	
	Gossmann H.	- Geographisches Institut der Universität, Freiburg	UF/GI
	Van der Ploeg R.	- Institut für Bodenkunde und Waldernährung	UG/IBW
Calandro A.		Italy	
		- Centro Studi Applicazioni Tecnologie Avanzate, Bari	CSATA
	Borriello L. Cavazza L.	- Istituto di Agronomia Generale e Coltivazioni Erbacee Università di Bologna	UBO/IAGCE
	Milella A.	- Istituto di Agronomia e Coltivazioni Arboree, Università di Sassari	USS/IACA
	Pacucci G.	- Istituto di Agronomia e Coltivazioni Erbacee, Università di Bari	UBA/IACE
	Maracchi G.	- Istituto di Agronomia Generale e Coltivazioni Erbacee, Università di Firenze	UFI/IAGCE
	Posa F.	- Istituto di Fisica, Università di Bari	UBA/IF
	Marcolongo B.	- Istituto di Geologia Applicata, CNR Padova	IGA
	Pietracaprina A.	- Istituto di Mineralogia e Geologia, Univ. di Sassari	USS/IMG
	Lechi G.M.	- Istituto per la Geofisica della Litosfera, CNR Milano	IGL
	Tombesi L.	- Istituto Sperimentale per la Nutrizione delle Piante, Roma	ISNP
	Rosini E.	- Ufficio Centrale di Ecologia Agraria, Roma	UCEA
Feddes R.A.		Netherlands	
	Feddes R.A.	- Instituut voor Cultuurtechniek en Waterhuishouding, Wageningen	ICW
	Van Ulden A.P.	- Koninklijk Nederlands Meteorologisch Instituut, De Bilt	KNMI
Mc Culloch J.G.		United Kingdom	
	Kirkby M.J.	- Department of Geography, University of Leeds	UL/DG
	Savigear R.A.G.	- Department of Geography, University of Reading	UR/DG
	Mc Culloch J.G.	- Institute of Hydrology, Wallingford	IH

HEAT·CAPACITY MAPPING MISSION (HCMM) COVERAGE EUROPE DAY

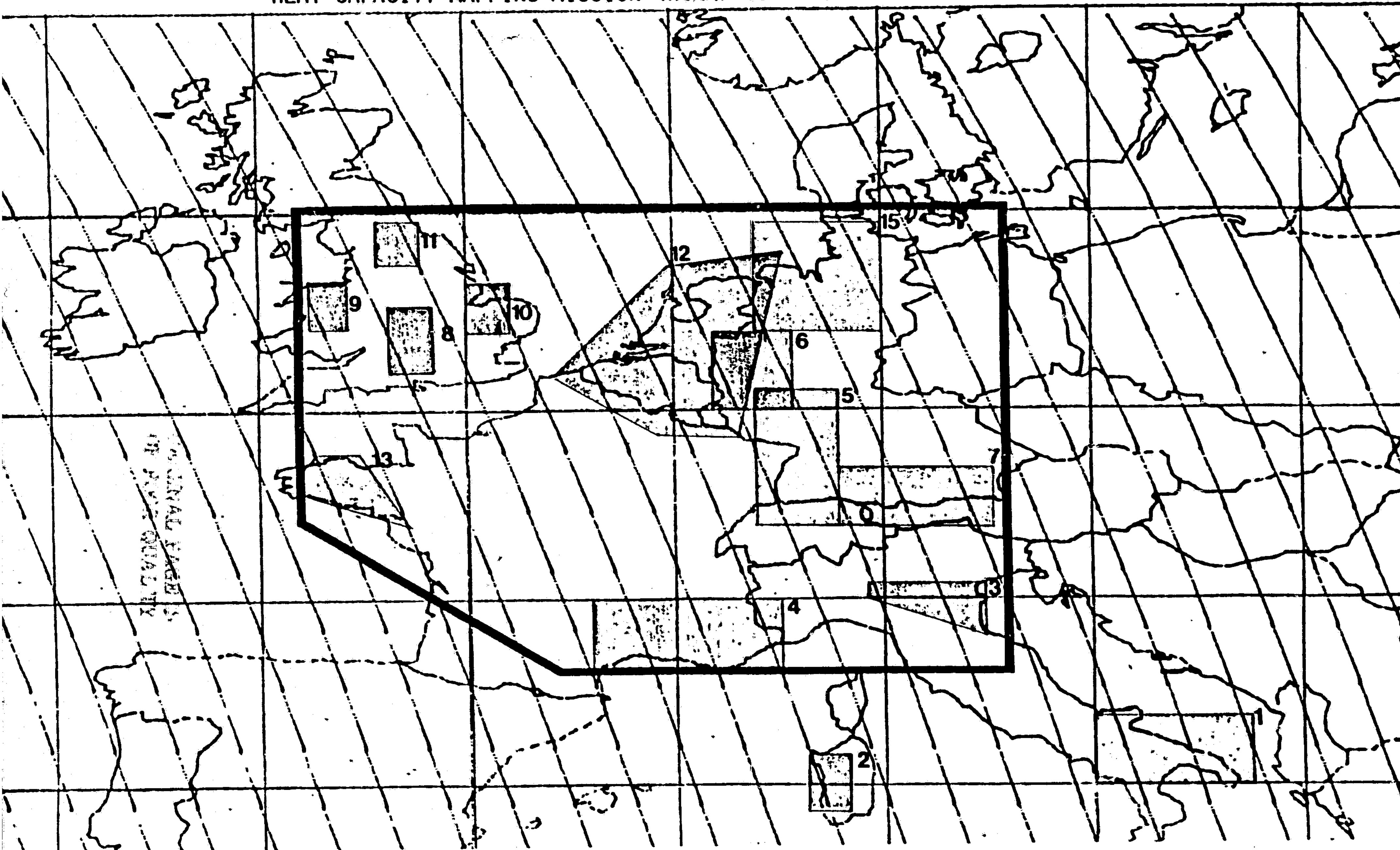

Fig. 1 SPATIAL DISTRIBUTION OF TELLUS TEST-SITES WITHIN THE EUROPEAN OVERALL TEST AREA

2.1. The Co-investigators

The names and abbreviations of the University Departments and Institutes participating in the TELLUS mission are listed in Table 1. Coinvestigators framework consists of six groups. The JRC Ispra and some EC's Directorates General make up the PI's leading group.

2.2. The Test-sites

Geographic as well as technical considerations led to arrange in five groups the fifteen test-sites as originally proposed by the Coinvestigators. No particular test-site was proposed by the JRC Ispra within TELLUS. His research staff works in collaboration with TELLUS coinvestigators on their national test-sites. A test-site coordinator was designated for each group according to the Institutes involved.
Arrangement in groups of TELLUS Test-sites is reported in Table 2. Fig. 1 shows the distribution of the test-sites proposed by Coinvestigators within the overall test-site "Europe" which was agreed by JRC and NASA (boundary in brackets).

2.3. Mission's objectives

According to the interest of the EC Commission and the research proposals made by the Coinvestigators, there are three main thematic lines of investigation:

1. Evaluation of evapotranspiration and moisture content of bare soils and of soils covered by vegetation.

2. Study of the interaction between natural phenomena and mesoscale heat budget.

3. Man-made changes and their impact on regional heat budgets.

Table 2 : TELLUS test sites, arranged in groups.

Test-Site Group	Test Site	N°
ITALY	Puglia and Basilicata*	1
	Sardegna	2
	Emilia	3
FRANCE	Bouches du Rhône	4
	Bretagne	13
GERMANY	Rhine Valley 1	5
	Rhine Valley 2	6
	Northern Alps	7
	Northern Germany	15
UNITED KINGDOM	England 1	8
	Wales	9
	England 2	10
	England 3	11
BENELUX	Benelux	12
DENMARK	Greenland**	14

*) Basilicata proposed by UR/DG

**) No HCMM receiving station

3. DATA RECEPTION AND DISTRIBUTION

JRC receives the HCMM data from two origins:

1) from NASA/GSFC
2) from CMS Lannion (EARTHNET)

For more details please refer to the 1st PR, Chapt.5 pg.9 and the 2nd PR, Chapt.3, pg.3.

3.1 NASA/GSFC data delivery

3.1.1. Standing Order data. Situation at Aug. 31st, 1980

At this moment of TELLUS' investigation no more Standing Order (SO) data can be waited for at the JRC and we may draw an overall conclusion of the normal SO distribution.
Historically, let us briefly recall the flow rate of SO data from Greenbelt to Ispra.
In Autumn 78 preliminary data arrived first, on form of transparencies and tapes, whereas the SO data (DVIS, DIR, NIR) started arriving early March 1979 on form of neg. transparencies (24 cm x 24 cm).
The well known delay of Standing Order data led to the establishment of the Priority Processing List (PPL) agreed by all Principal Investigator and NASA in Jan. 1979.
In spite of such initiative the NASA response to the PPL was surprisingly poor. At the end of March 1980 nearly 56% only of the PPL was satisfied (see Table 6).
Now, at the end of the final distribution the response to the PPL is increased slighty in respect to the preceding one (see Table 7). As a matter of fact it does still remain less than 63% although one must recognize that every effort has been made by the HCMM staff to compensate the delay.
Up to now the JRC has received sets of scenes of 368 orbits, but the 38 processings of 370 scenes made by NASA from March till August did not satisfy exhaustivelly the PPL.
It is therefore understandable that various TELLUS Co-Investigators (such as the French ones) waited till the end of SO distribution -as formally established - to decide whether

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TABLE 3. STATUS OF PRIORITY PROCESSING LIST AT MARCH 31st, 1980

MONTH	REQUESTS										RESPONSES										FAILED	
	G		BNL		F		UK		I		G		BNL		F		UK		I		TRACKS	
78	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
May	3	3			2	2			4	4	3	2			1	1				1		1
June	1	1			1	1			7	7	1	1				1			1	2		1
July			2	2	2	2	2	2	9	9			2	2	1		1		5	3		5
August	1	1			4	4			10	10		1			1	3			5	2		2
September					5	5	3	3	7	7					4	4	1	2	4	4		1
October	5	5			2	2			2	2		4				2				1	3	
November	1	1			4	4	1	1	3	3	1	1			3	2		1	1	2		
December	1	1			2	2						1				2					2	
Jan 79	1	1										1										
TOTAL	13	13	2	2	22	22	6	6	42	42	5	11	2	2	10	15	2	3	16	15	5	10

$$\frac{\text{RESPONSES}}{\text{REQUESTS}} = 56.4\%$$

Legend:

B : Benelux
G : Germany
F : France
I : Italy
UK: United Kingdom

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TABLE 4. STATUS OF PRIORITY PROCESSING LIST AT AUGUST 31st, 1980

MONTH	REQUESTS										RESPONSES										FAILED	
	G		BNL		F		UK		I		G		BNL		F		UK		I		TRACKS	
78	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
May	3	3			2	2			4	4	3	2			1	2				2		1
June	1	1			1	1			7	7	1	1				1			3	2		1
July			2	2	2	2	2	2	9	9			2	2	2		1		6	2		5
August	1	1			4	4			10	10					1	4			4	3		2
September					5	5	3	3	7	7					5	5	1	2	4	4		1
October	5	5			2	2			2	2		5				2				1	3	
November	1	1			4	4	1	1	3	3	1	1			2	3		1	1	2		
December	1	1			2	2						1				2					2	
Jan 79	1	1										1										
TOTAL	13	13	2	2	22	22	6	6	42	42	5	11	2	2	11	19	2	3	18	16	5	10

$$\frac{\text{RESPONSES}}{\text{REQUESTS}} = 63{,}4\%$$

Legend:

B : Benelux
G : Germany
F : France
I : Italy
UK: United Kingdom

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to keep to the PPL or try to look for other Night/Day pairs. Some others instead gave up the first one and repetitively asked for Retrospective Orders (RO).
The Table 5 does reflect the actual distribution of Standing Order data made via Ispra. A comparison between the situation of the responses to the PPL and the actual RO distribution per country may offer an interesting indication.

3.1.2 Retrospective Order Data

Retrospective Order data were requested by many Coinvestigators after reception of Standing Order data.
CCT's of 101 scenes (DVIS-DIR-NIR) have been requested and 95 of them have been received by the JRC and distributed.
Four "scenes" with Temperature Difference (TD) data and Apparent Thermal Inertia (ATI) data have also been requested and received.
The overall RO situation has been resumed in Table 6.

3.1.3 Priority Coverage.

A series of priority coverage has been requested by various Coinvestigators to match with concommittant ground measurements or to establish an intercomparison with other satellite data (see list of Table 7).
The setting up has however revealed difficult owing to different misunderstanding. In 1978, it was difficult to establish whether the satellite could receive or not the data, because of congestion at the Madrid Station from other satellite transmissions. Sometimes no switching could be organized at all.
After March 1980 lowering of orbit gave difficulty to establish what was the actual track. as explained in 3.1.4.

3.1.4 Lowering of satellite's orbits

Finally let us consider an important factor affecting the distribution of the HCMM information: lowering of HCMM satellite which disturbed the whole 16 tracks cycle. The exact modification and consequences of this was not clearly specified in time to Coinvestigators when requesting Priority switch-on for special HCMM coverages to NASA. This inconvenient caused uncertainties and difficulties in organization of related ground-truth activities.

Table 5 DISTRIBUTION OF STANDARD ORDER SCENES PER COUNTRY AND TEST-SITE, made by J.R.C.

Test-site Group	Test site N°	Scenes N°	Repeatedly processed scenes	Scenes per country
Italy	1	75	6	259
	2	135	11	
	3	127	13	
	others	1		
France	4	185	15	319
	13	123	6	
	others	90	5	
Germany	5	81	2	185
	6	77	4	
	7	77	4	
	15			
	others	2		
Benelux	12	136	13	142
		6		
United Kingdom	8	77	3	173
	9	78	4	
	10	69	3	
	11	64	4	
	others	39	1	

Table 6. R.O. SCENES ON CCT's AT AUG. 31st, 1980

	NASA/GSFC	EARTHNET/CMS Lannion	Total
Ordered	101	74	175
Received	95	71	166
Still not received	6	3	9

Total distribution per country		
	Germany:	73
	Italy :	15
	Benelux:	31
	France :	41
	United Kingdom:	12

Table 7. Priority Coverage by Madrid or Lannion Stations.

(switching-on of satellite and tracking)

	ZONE	DATE	N	D	ORBIT NO	TRACKING ON	TRACKING OFF
78	Sibari	24.07.78	+		1314	02.32	02.45
	39.44/16.27E	24.07.78		+	NO SWITCHING ONLY NIGHT		
		25.07.78		+	1328	01.14	01.26
		30.07.78	+		1402	01.08	01.17
		30.07.78		+	1410	13.38	13.49
	UK						
		07.07.78	+		1063	03.35	04.05
		07.07.78		+	1070	14.49	15.00
79	UK						
	53/1.5W	30.08.79	+		7268	00.47	00.52
		30.08.79		+	7276	13.16	13.26
		29.09.79		+	7721	14.09	14.16
	Pattensen						
	52.15/9.48E	20.06.79	+	+	NO SWITCHING ALL N/D		
		21.06.79	+	+	NO SWITCHING ALL N/D		
		22.06.79	+		6246	00.58	01.03
	Venice	06.10.79	+		7816	00.30	00.35
		06.10.79		+	7824	12.58	13.08
	Puglia	17.11.79	+		8438	00.13	00.18
		17.11.79		+	8445	11.10	11.26
					8446	12.43	12.53
					8447	14.22	14.27
		18.11.79	+		8453	00.31	00.36
		18.11.79		+	8461	13.01	13.11
		22.11.79	+		8512	00.07	00.12
		22.11.79		+	8519	11.04	11.09
					8520	12.35	12.46
		23.11.79	+		8527	00.24	00.29
		23.11.79		+	8534	11.20	11.28
					8535	12.54	13.04
80	Grendon						
	39.44/16.27E	16.05.80		+	11148	12.15	12.25
		17.05.80	+		NONE	NONE	
		17.05.80		+	11 163 (TS disturbed)	12.11	12.22
		18.05.80	+		11 171	00.48	
		18.05.80		+	11 178	11.58	
		19.05.80	+		11 186	00.43	
		19.05.80		+	11 193	11.52	
		20.05.80	+		NONE	NONE	
		20.05.80		+	11 208 (not good)	11.55	12.02
		21.05.80	+		NONE		
		21.05.80		+	11 223	11.49	11.56
		22.05.80	+		11 231 (not TS)	00.25	
		22.05.80		+	NONE	NONE	

3.2 ESA/EARTHNET data delivery

From May 1979 CMS Lannion has been producing and distributing regularly Quick-Looks for an amount of 527 orbits. Table 8 shows the distribution of the Quick-Looks orbits by CMS Lannion to TELLUS Co-investigators.

Several Co-investigators after reception of Quick-Looks, requested the Retrospective Order data using procedure of standard cutting of the orbits (see 2nd PR, Chapt. 3.2.2). Retrospective Orders were requested for both transparencies and CCTs. CCTs have been ordered for an amount of 74 scenes, 71 of which have been received by JRC and distributed (see Table 6).

The good organization of CMS Lannion and the very easy contacts being possible with them have created a regular exchange flow of requests an answers following the scheme of Fig.2, 2nd PR, Chapter 3.

Table 8 QUICK LOOK DISTRIBUTION BY CMS LANNION TO TELLUS TEST SITES GROUPS

Table 8a NIGHT ORBITS

Track	JRC	I	G	BNL	F	UK
2.1	X	X				
13.1	X	X				
8.1	X	X				
3.1	X	X				
14.1	X	X				
9.1	X	X	X			
4.1	X	X	X			
15.1	X	X	X		X	
10.1	X	X	X		X	
5.1	X	X	X	X	X	
16.1	X	X	X	X	X	
12.2	X	X	X	X	X	
6.2	X		X	X	X	
1.2	X		X	X	X	X
12.2	X		X	X	X	X
7.2	X		X	X	X	X
2.2	X		X	X	X	X
13.2	X			X	X	X
8.2	X			X	X	X
3.2	X				X	X
14.2	X				X	X
9.2	X				X	X
4.2	X					X
15.2	X					X
Total N Tracks	24	12	12	10	15	11

Table 8b DAY ORBITS

Track	JRC	I	G	BNL	F	UK
18.3	[illegible]					
8.1	X	X	[illegible]			
3.1	X	X	X			
14.1	X	X	X			
9.1	X	X	X	X		
4.1	X	X	X	X		
15.1	X	X	X	X		
16.1	X	X	X	X	X	
5.1	X	X	X	X	X	
16.1	X	X	X	X	X	X
11.2	X	X	X	X	X	X
6.2	X	X	X	X	X	X
1.2	X	X	X	X	X	X
12.2	X			X	X	X
7.2	X			X	X	X
2.2	X				X	X
13.2	X				X	X
8.2	X				X	X
3.2	X				X	X
14.2	X				X	
Total D Tracks	19	12	11	11	13	10

Table 8c OVERALL NUMBER OF N/D TRACKS

Tracks	JRC	I	G	BNL	F	UK
Night	24	12	12	10	15	11
Day	19	12	11	11	13	10
N + D	43	24	23	21	28	21

4. ACTIVITY PERFORMED AND RESULTS OBTAINED.

4.1 Evaporation and soil moisture

4.1.1 Soil covered by vegetation

4.1.1.2 Taylor's expansion of the surface energy balance equation (ICW)

The surface energy balance equation was linearized using Taylor's expansion. In this way, the original hypersurface in seven dimensions could be reduced to a linear relationship between evaporation and surface temperature, or to a surface relationship involving evaporation, surface temperature and albedo.

These analytical approximations permit a rapid sensivity analysis of the surface energy balance equation as well as a speedy mapping of evaporation from remotely sensed surface temperatures and albedo.

Results obtained by this method from aircraft MSS data in a desert area were compared with evaporation measured on the ground. The standard deviation of the regression line of calculated on measured evaporation was 1.0 mm/day.

Details of the method are reported in TELLUS NEWSLETTER 15 (Annex 3).

4.1.2. Field operations

4.1.2.1 Flight experiment

4.1.2.1.1. Germany (JRC, UG/IBW, UL/DG, UR/DG, IHW)

At the end of the EJMC at Pattensen (June 1979) it was decided that the various Institutes participating to the campaign would give their contribution to a report describing the type of measurements taken and the equipments used and all the technical details necessary to data processing (see Annex 1).
In principle this report was thought as a guide to data retrieval for people participating to the campaign and it should have been issued by the end of 1979 without experimental data. Unfortunately JRC did not receive the contributions in due time.
In the meantime some contributions with experimental data were received and it was decided as a first step to put them in the report. In any case almost all the experimental data are at Ispra and are available to the various Institutes which participated to the campaign.
JRC-Ispra, which did the micrometeorological measurements on the test field N° 1 (bare soil) has already spoiled all the data and used them as input for the first run on the TELL-US model. Although the results appear to be reasonable they are still waiting to be confirmed with final data on soil thermal properties.

4.1.2.2. Continuous field measurements.

4.1.2.2.1. Italy

Policoro campaign 1979 (JRC, UBA/IACE, CSATA).
After the first measurement campaign in 1978 (see 2nd Progress Re-

port, pag. 18) a 2nd measurement campaign has been carried out in 1979 to test evapotranspiration and soil moisture models as TERGRA in semiarid conditions.
Testing the validity of such models in these particular conditions is one of TELLUS aims.
In fact both the favourable cloud cover conditions existing in the Mediterranean and African areas and the more homogeneous land structure existing in many African regions (compared to European ones) make future HCMM and/or thermal satellites more suitable for evapotranspiration and soil moisture applications.
This TELLUS item lines up with the Commission's initiatives in favour of the Associated and/or Developing Countries. It is also view as an initial contribution to solving overhanging desertification problems.
Wheat was the crop choosen owing to the great importance of it.
In April-May 1979 a measuring campaign was made on winter wheat.
The campaign was carried out by the JRC staff. UBA/IAGCE and CSATA worked under contract.
The JRC team equipped the field of 350 x 100 m for micrometeorological and radiometer instrumentation with an automatic data acquisition system.
The Agronomy Institute of the Bari University was in charge of the measurement of crop-and-soil parameters.
The CSATA, Bari had the task to staff the test area, maintain the equipments,unloading and loading the magnetic recorder, and control that the system was working properly. The ICW, The Netherlands (Dr. R.A. Feddes) acted as advisor about the preparation of the campaign. ICW is pretty interested in following data interpretation and in results obtained.
The parameters measured were the same as those of the 1st measuring campaign on grass (Table 9) while some other parameters have been particularly stressed in this campaign (Table 10).

Table 9

- net radiation
- solar radiation
- albedo
- incident long-wave radiation (sky radiation)
- VIS-NIR and IR radiation
- soil temperature (at four depths)
- heat flüx into the soil (at two depths)
- dry and wet bulb temperatures (Bowen ratio)
- wind, velocity and direction
- atmospheric pressure
- soil moisture (tensiometers and drilling)
- soil characteristics (composition, pF curve, ecc).

Table 10

- rooting depth and distribution
- crop height and crop weight vs. time
- leaf area index
- organic matter

JRC's data acquisition system proved to be highly reliable (only some percents of data have been lost owing to local electrical mains failure).
All the data have been collected and seem to be consistent, but due to previous engagements (Pattensen campaign) their processing had to be postponed.

4.2 Heat Budget

4.2.1 Natural phenomena

This part of the investigation concerns mesoscale heat budgets not particularly affected by man-made heat release. It consists in particular in a study of the relation between different land use pattern and surface temperature as well as the relation between topography and surface temperature.

4.2.1.1 Analysis of thermal infrared digital data recorded over Belgium. (KUL/LBB)

The data analyzed was a CCT of night pass over Belgium on May 30, 1978 (AA 0034.0212.0.3). It was attempted to establish relations between the surface temperature on one hand and soil type and forests on the other.

Methods. The digital HCMM data was visualized in form of a computer printout. The Belgian territory represented a printout of 2 x 1.5 m which, after photographic reduction of about 50%, served as the basic material for the interpretation. Further printout maps were made by introducing class limits of temperature. By means of a zoom transfer-scope these computer printout maps were optically superposed and compared with different type of maps or LANDSAT images.
The maps were road maps, soil association maps and maps of forested areas, while the LANDSAT imagery were scenes recorded on 17.5.76, 10.4.76, 23.3.73 and 22.5.77. The LANDSAT scenes principally served to identify currant land use.

Results

- Forests: Forested areas in the Ardennes could be well delineated by their higher surface temperatures. However the difference between coniferous and deciduous forest types or differences between species could not be inferred from the surface temperature map. (see Fig. 3-5 of Annex 2)

- Soil types: A distinction could be made between wetter soils in the Polder area having a high clay content and sandy soils and sandy loam soils. Especially dune areas showed high temperatures. More details, also in the form of maps are given in TELLUS NEWSLETTER 10 (Annex 2)

4.2.1.2 The influence of topographic structures on night-time surface temperatures. (UF/GI)

The data base for this investigation was provided by a segment of HCMM scene AA 0034. 0213.0.3 of May 30, 1978. It encompasses the Upper Rhine Valley between Basel and Frankfurt and the surrounding highlands.
The segment was rectified with respect to Gauss-Krüger coordinates and individual sections were superposed on the corresponding sheets of the Official Topographic Map 1:200.000 of the Federal Republic of Germany (TUK 200). Details of the procedure were described in TELLUS NEWSLETTER 12 (Annex 5 of 2nd Progress Report).

Geometric Resolution and Suitable Map Scales. Under the assumption that the minimum diameter of map elements in thematic and topographic maps is 0,3 mm, the geometric resolution of the VHRR (Very High Resolution Radiometer) of the HCMM of 600 m corresponds to the scale 1:2.000.000. For this reason, we were somewhat sceptical wether an enlargement to the scale of the TÜK 200 and the superimposition of the enlarged image with the various levels of information provided by this map would lead to an increase in knowledge.
The material presented in this study shows that HCMM harbors an abundance of information which is only revealed by means of this kind of processing. This is especially true for the correlation between surface temperatures and the water network as well as of the relationship between surface temperatures and the settlement pattern.
However, we should note that the resolution of the HCMM is not sufficient to determine the boundaries of various geographic units or to establish the exact limits of topographic structures by means of the HCMM image.
Nevertheless, it is essential to state that the thermal pattern of an HCMM image at this scale can be related to and explained by topographical structure.

<u>Night-time Surface Temperatures and Relief.</u> A well known rule of topoclimatology is the thermal tripartition of hilly or mountainous areas at night: cold elevations, warm slopes and cold valley bottoms. The data allows us to test the applicability of this law to the behaviour of surface temperatures in various spatial dimensions.

In general, only the difference between cold valleys and lowlands on the one hand, and warm slopes and mountain tops on the other, could be verified. Valleys are considerably colder than slopes if covered by comparable vegetation. The water network which follows the valley systems is all but congruent with the distribution pattern of particularly cold surfaces. This applies not only to the valleys in the highlands carved to a depth of hundreds of metres, but also to differences in elevation amounting to less than one metre on the alluvial and diluvial plains of the Upper Rhine Valley (cf Fig.'s 10a and 16c of Annex 4).

Nevertheless, the elevated areas proved to be as warm as the slopes, in some cases even noticeably warmer (Soonwald, Pfälzer Wald, Westtaunes, edge of the Black Forest near Offenburg) in most of the image sections presented here. Cold elevated areas can be found in these samples only in places where one of the following three conditions is met:

Grassland and cultivated fields in altitude above forested slopes

Extended plateaux (cf Fig. 20a of Annex 4)

Extended surfaces in areas with small differences in elevation (cf Fig. 9b of Annex 4)

At the mesoscale, if we do not consider each mountain or valley individually, but designate the whole Upper Rhine Valley as the "cold lowland", the entire, strongly dissected highland fringe as the "warm slope" and the highland plateau which decline slightly towards the edges of the image, as the"cold elevation", we can establish virtual congruence between the model and reality.

<u>Surface Temperatures and Forest Distribution</u>

It is generally agreed that forests do not cool off as rapidly at night as do unforested areas and that they, consequently, produce higher surface temperatures at night than adjoining grassland or cultivated fields.

Therefore, it is surprising that a much more complex picture resulted from this study:

- Forests on steep slopes or convex terrain show very high temperatures (as warm as city centres).
- All forests on the plateau of highlands display slightly lower temperatures but are definitively warmer than scattered clearings or adjoining unforested terrain. With the exception of the Upper Rhine Valley, the contrast between forested and unforested terrain is the most essential factor of the distribution of warm and cold surfaces everywhere, unless, of course the relief determines the thermal pattern.
- In the Upper Rhine Valley, the picture is very complex. The residual forests on the holocene flood plain of the Rhine are depicted as being relatively warm but only in places where they have not lost their characteristic features due to the canalization of the Rhine River and the subsequent drop of the ground water level. The forests on the diluvial and alluvial fans in front of the Pfälzer Wald and the northern Vosges Mountains also seem to be warmer than their surroundings. On the other hand, most of the Hardt forests on the Rhine's quarternary accumulation plain and in part on the gravel fans of the rivers of the Black Forest, are as cold as, or even colder than, neighbouring unforested areas. This is most evident in the southern part of the Upper Rhine Valley north of Basel.

If one ignores the behaviour of the residual forest on the Rhine's holocene flood plain, a general tendency for great contrast between forested and unforested areas on convex landforms and for reduction of this contrast between the two types of surfaces in concave terrain prevails. As we have stated repeatedly, the highest surface temperatures are found on forested mountain ridges and steep slopes.

There must be several reasons for the distinctive behaviour of forested surfaces.

- The low surface temperature of the Hardt forests can only be understood if one assumes that there is a relatively homogeneous layer of cold air extending beyond the actual height of the trees (inversion in the boundary layer).
- The differing behaviour of forests on plateaux can then be explained by the fact that a sufficiently extended layer of inversion could not be created there because of stronger dynamic turbulances caused by winds at relatively high speeds. The sensible heat flux to the forested surfaces thus remains greater than on adjoining grassland and arable fields.
- All this signifies that the much higher surface temperatures of forests at night cannot be attributed to, or at least not completely explained, by the capacity for heat storage within the forest but rather also by the sensible heat flux between the air and the forest.
- The explanation for the relatively high temperature of the residual forests on the holocene flood plain of the Rhine can be derived from the fact that, on the one hand, a greater heat capacity is available below the surface of the forest because of numerous residual water bodies and that, on the other hand, inversion in the boundary layer is interrupted or at least weakened, as in large cities.

Cold Air Reservoirs and Cold Air Streams. With reference to the problem of cold air accumulation in concave areas and its outflow from valleys, the following statements can be made:

- The fact that broad and shallow valley expanses are generally depicted as cold areas independent of their surface coverage, supports the theory that the thermal image can identify areas in which cold air collects and either comes to rest or flows onward very slowly down the valley. By contrast, in narrow valley areas, those sections where cold air escapes quickly are registered as warm areas. Furthermore, in contrast to cold air reservoirs, the areas in front of the mouths of valleys were nowhere registered as particularly cold areas.

This signifies that basins accumulating cold air are depicted by the satellite thermal image, but that the route taken by the cold air and the extension of cold air at the mouth of a valley is ignored.

- It is generally agreed that elevated grassland is the main producer of cold air and that it is prerequisite for the night-time streams of cold air at the mouths of valleys, as grassland gets colder than adjoining forests. Our examples show, however, that extensively or completely forested areas can also create cold air accumulations.
  Basically, this was to expected. From the point of view of the heat budget, elevated forest areas with their higher surface temperatures must surely radiate more energy and thus the net radiation is even more negative than over grasslands. Therefore, forests have to withdraw a larger quantity of energy from the air via the sensible heat flux and so contribute substantially to the cooling of the air. Forests do not produce air that is as cold as that of grassland in corresponding locations but they produce it in greater quantities.

Comparison of Airborne and Satellite Thermal Images. There are several advantages for working with satellite thermal images as opposed to aerial IR-registrations. It is much easier to rectify a satellite image geometrically and to superimpose other levels of digitized information on it.
An advantage for satellite thermal images is essentially based on the possibility of recording large areas almost simultaneously. The recording of an area of the size of the Upper Rhine Valley would require hours using the planes currently available for civilian research and would result in data loaded with discrepancies caused by the time lag between the beginning and the end of the registration. Of course, if we are faced with the problem of clarifying the boundaries of areas with varying thermal behaviour with a degree of accuracy of less than 600 m, the actual satellite data cannot be used. Satellite data supplied the same information as aerial IR registrations with corresponding averaging for all studies requiring a survey of the thermal pattern within an area measuring 10 km x 10 km ore more (cf Fig. 15 of Annex 17) provided that sufficiently precise control points can be established

for the purpose of geometric rectification in the surroundings of the area under discussion.
Generally, this does not present any problems in areas with a strong relief. Satellite thermal data are much more comprehensive than aircraft data for studies on a regional, rather than a local scale, since air-borne thermal images often obscure the basic correlation in thermal patterns because of a variety of irrelevant topographical detail.
Satellite thermal images certainly demonstrate the dependence of surface temperature on relief much more clearly than comparable air-borne thermal images.

Further details of this study are given in TELLUS NEWSLETTER 17 (Annex 4).

4.2.2 Anthropogenic heat release (UF/GI)

The data base for this investigation was provided by a segment of HCMM scene AA 0034. 0213.0.3 of May 30, 1978. It encompasses the Upper Rhine Valley between Basel (47°33'N, 7°36'E) and Franfurt (50°7'N,8°36'E) and the surrounding highlands.
The geometric corrections of the scene relative to the Gauss-Krüger coordinate system at a scale 1:200.000 were carried out as described in TELLUS NEWSLETTER 12.

Surface Temperatures of Settlements. It was to be expected that heat islands from large cities would be depicted in the HCMM image because of their high surface temperature. However, it became evident that much smaller settlements can evoke a signal, under favourable circumstances, down to a size of 2.000 inhabitants.

Prerequisites for this phenomenon are a densely built-up village centre and placement in a horizontal, unforested environment. Otherwise, the weak signal emitted by the settlement would be masked by other effects on the thermal pattern. Especially the thermal effect of such small villages situated in concave terrain is cancelled out by the influence of the relief.

However, not nearly all of the villages with the above mentioned favourable conditions are represented by a warm spot on the HCMM image, as the recorded phenomena are very small with reference to the means provided by geometric as well as radiometric resolution. The effect is of the same magnitude as the random noises produced by VHRR. Thus it is possible that the heat island of a village can be simulated or suppressed in each individual case. At the same time, the identification of a village depends on wether its area is depicted in a single pixel or wether it is distributed on several picture elements. A signal on the thermal image can be expected only in the first case.

The situation is less equivocal when we consider larger villages, and smaller towns with an average size of approximately 10.000 inhabitants. These are clearly identified as heat islands by reason of their elevated surface temperature. The core area of every larger city with tens of thousand of inhabitants is registered as a heat island with temperatures a few degrees higher than its surroundings.

The difference in temperature between the centres of cities such as Mannheim/Ludwigshafen (cfr.Fig.12 of Annex 4) and Strasbourg (cfr.Fig.13 of Annex 4) and their environments increases to over 4°C.

The area of higher surface temperature extends beyond the urban built-up area to the surroundings because of the flow of warm air in the boundary layer. The suburban area is much warmer on the leeward than on the windward side of the cities.

Industrial Complexes. On comparing different industrial areas, it becomes apparent that different levels of energy consumption are identified on the thermal image even though it is impossible to quantify the respective heat emission of an automobile plant and a chemical factory from the difference in the temperature reading. It is difficult to interpret these readings definitively because the thermal image by itself cannot be used to establish decisively wether the high temperatures of chemical plants registered by the HCMM are really higher surface temperatures or wether they must be attributed to the masking effect of warmer exhaust gases containing aerosols.

For further details of this study you are referred to TELLUS NEWSLETTER 17 (Annex 4).

4.3 Satellite data calibration and atmosphere corrections

4.3.1 Validation of HCMR Calibration

4.3.1.1 Water surfaces

4.3.1.1.1 Lake Geneva (JRC)

Lake Geneva is one of the largest lakes of Europe with a surface of 581 km^2 and a maximum depth of 310 m. The availability of water surface temperatures and a considerable number of suitable HCMM scenes make it a rather attractive reference target.

Ground reference temperatures. The International Commission for the Protection of Lake Geneva measures lake temperatures at monthly intervals at 15 points in the lake. Surface temperatures from 10 points in the "Grand Lac" were used in this investigation. The mean lake temperature was calculated for each month and a seasonal mean temperature curve was constructed by linear interpolation. This curve, and the curve of ± one standard deviation are shown in Fig. 2 and supplied the ground reference temperatures.

HCMM scenes. CCT's of eight satellite scenes between June 3 and Oct. 11,1978 were employed. The lake surface was delimited on a video screen and the mean surface temperature and its standard deviation was calculated. In most cases, the thermal image could directly be used for this purpose, except for autumn scenes where contrast between water and land was not sufficient. The visible channel was employed in these cases.
Slight problems were posed by the contrails of aircraft as a major European N-S air lane passes over the lake. Contrails as well as clouds were excluded from the temperature calculations.
The scenes employed are listed below:

Date	Scene
3.6.78	AA 0038.0148.0.3
17.7.78	AA 0082.0208.0.3
	AA 0082.1305.0.1,2
28.7.78	AA 0093.0210.0.3
	AA 0093.1307.0.1,2
22.8.78	AA 0118.1232.0.1,2
18.9.78	AA 0145.1237.0.1,2
10.11.78	AA 0198.1221.0.1,2

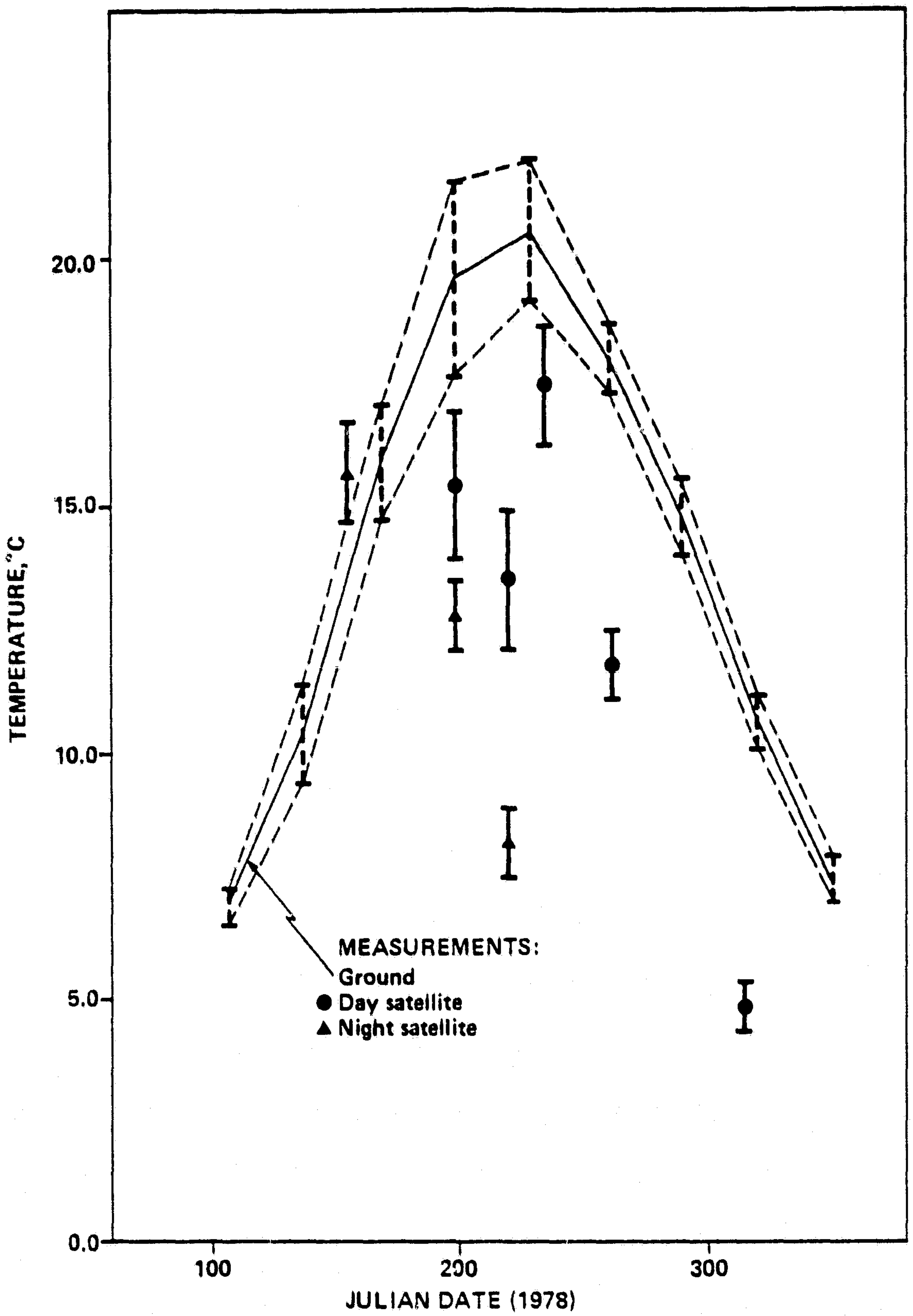

Fig. 2 : Seasonal trend of the surface temperature of Lake Geneva. The stippeled lines and the bacs indicate the standard deviation.

Atmospheric corrections. These corrections were calculated with the RADTRA model using a coefficient K2 of 10. Atmospheric soundings from Payerne, 30 km N.E. of the Lake, were taken from the European Meteorological Bulletin and served for the calculations. Only the CC GMT soundings are published in the Bulletin and these had to be employed to correct both day and night temperatures.

The 12.00 GMT air temperature at the surface was inserted for the day time corrections.

Emissivity. The radiometric temperatures were converted to physical temperatures by assuming an emissivity of water equal to 0.9815 (Becker et al, 1980).

Results. Satellite and ground measured lake temperatures, as well as the atmospheric correction are presented in the table below, while Fig. 3 gives the seasonal trend of the two temperatures together with their standard deviation.

TABLE 11

DATE	TIME	HCMM*	ATM.CORR. °C	HCMM °C**	GROUND °C
3.6.78	night	13.0	+ 1.0	15.7 ± 1.0	13.8 ± 1.2
17.7.78	night	12.0	- 0.5	12.8 ± 0.7	19.7 ± 2.0
	day	14.1	- 0.1	15.4 ± 1.5	
28.7.78	night	11.0	- 4.1	8.2 ± 0.7	20.0 ± 1.6
	day	14.4	- 2.3	13.5 ± 1.4	
22.8.78	day	15.7	+ 0.3	17.4 ± 1.2	20.1 ± 1.2
18.9.78	day	11.8	- 1.3	11.8 ± 0.7	17.6 ± 0.6
10.11.78	day	3.6	0.0	4.8 ± 0.5	11.3 ± 0.6

* radiative temperature

** temperature after correction for emissivity and atmospheric effects

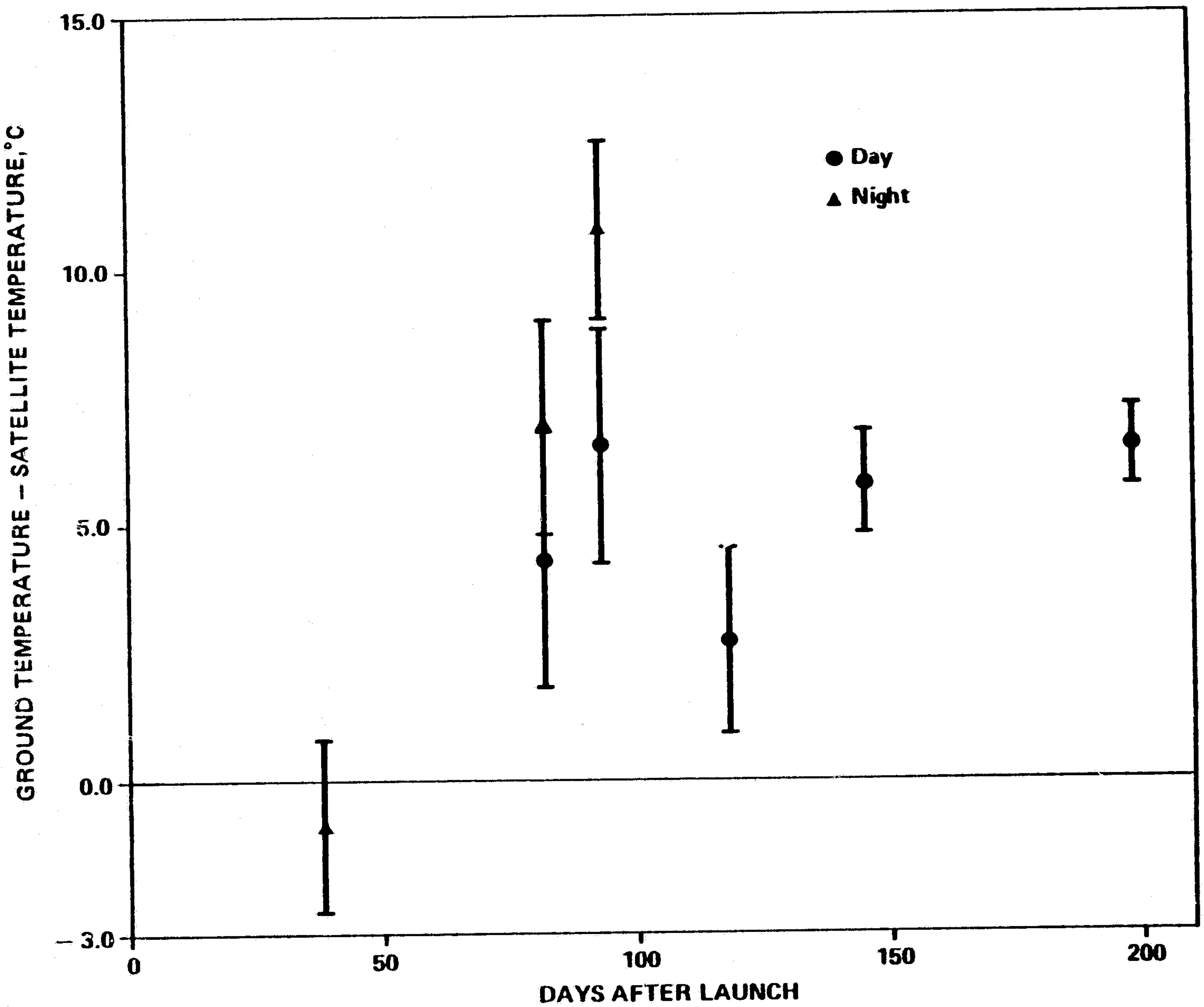

Fig. 3 : The difference ΔT, ground temperature-satellite measured temperature, as a function of the days after launch.

Except for June 5, satellite temperatures are lower than ground temperatures, while the standard deviation from the mean is approximately the same for both, or somewhat lower for the satellite temperatures.
The standard deviation for night data is lower than for day data. As effects of the scan angle are negligible at the dimensions of the lake, the standard deviation for both the satellite and ground data is a measure of spatial variability.

In Fig.3 , the difference between ground and satellite measured lake surface temperatures ΔT , is plotted as a function of days after launch.
On the basis of this data it is certainly difficult to reach a definite conclusion on the behaviour of the HCM Radiometer.
Only one day point, 38 days after launch, corresponds with the corrected calibration which was applied on the basis of the White Sands data acquired somewhat earlier by NASA.
The remaining five ΔT (day) range between 2.7 and 6.5°C and, in view of the rather important standard deviations, one could as well deduce a constant understimation of the time temperature by about 5°C or an oscillation of the calibration, the assumption being made that the slope of the calibration curve remains constant with temperature.
The higher values of ΔT (night) seem in part to be due to the lowering of the surface temperature of the lake at night, but no measurements are available at the moment to confirm this hypothesis . (see also TELLUS Newsletter 18, Annex 6)

4.3.1.2 Land surfaces

4.3.1.2.1 Pine forest (UF/GI, atmos.corr. JRC)

A 1 x 1 km pine forest in the Upper Rhine Valley near Hartheim (47°12'N,7°36'E) could be identified on a night thermal image and served for this calibration attempt.

HCMM scene: AA 0034.0213.0.3 of May 30, 1978

Ground measurements: The energy balance of the pine forest was monitored at hourly intervals by the Meteorologic Institute of Freiburg University.
As the incoming and outgoing long wave radiation was measured above the canopy, the surface temperature of this canopy could be calculated.
An emissivity between 0.97 and 0.98 was assumed for the pine forest.

Results: Interpolating linearly for the exact time of the satellite overpass a surface temperature between 9.0 and 9.2°C was calculated which agrees with the satellite temperature of 8-9°C.

Atmospheric corrections calculated with the RADTRA model and radiosonde data from Stuttgard showed the effect of the atmosphere to be less than one tenth of a degree centigrade.
Further details are given in TELLUS Newsletter 18 (Annex 6)

4.3.2 Atmospheric corrections

4.3.2.1 Experience with the RADTRA model (JRC)

Serious difficulties were encountered in the routine use of this model.
It was noted that very slight changes in the dew point depression, especially at pressures below 800 mbar, had an eccessively large effect on the atmospheric correction.
The inability of the interpolation routine to deal with small or zero gradients seems to be the source of this difficulty which is illustrated by the following example:

Radiosonde data with 15 pressure levels; only four are indi cated:

mb	T°K	DPD,°C I	II
730	277	5.0	5.0
700	276	3.5	3.5
670	273	3.5	3.0
620	272	27.0	27.0

The atmospheric correction for a radiometric temperature of 288.3°K was + 9.8°K with data set I and +0.2 with data set II, a difference of 10°K for a change in the DPD of 0.5°C in one layer.
These problems have already been communicated to the HCMM Project Scientist. He has recognized that it was necessary to produce and distribute urgently a new version of the RADTRA model incorporating the changes suggested by TELLUS Co-is.

4.4 HCMM data simulation. Usage of filtering techniques for scaling-up simulation.

It is well known that the gray level of image's pixels depends on the radiance coming, in a particular spectral range,

from the ground areas corresponding to the pixels.
If each area is homogeneous no problem exists in its interpretation; if, on the contrary, a lot of different objects are contained, they contribute in different manners to the global gray level of the pixel.

The problem becomes more important as greater dimension pixels are involved. i.e. the problem must to be faced to understand the informative content of the data.

Images from HCMM are typical example of this with their pixels 500 x 500 m^2 dimensioned. It is then necessary to study the so called scale effect to understand how detailed informations aggregate to give rise to low or very low resolution data as they are detected for example from a high altitude platform.

The first question to which this work was devoted was the simulation of HCMM data starting form better resolution ones.

The methodology which permits the correlation of different resolution data is based on filtering techniques in the hyphotesis that all changes due to altitude increase can be represented by a point spread function. These aspects, together with a "practical" introduction to the filtering technique, are particularly pointed out all along the work.
Attention is here mainly focused on the scale effect in its general aspects also for its importance in problems such as registration between images and so on.
Details of the method are reported in Annex 6.

LIST OF TABLES

LIST OF FIGURES.

5. ABBREVIATIONS

AEM	Application Explorer Mission
AL	After Launch
ATI	Apparent Thermal Inertia
CC	Cloud Coverage
CCT	Computer Compatible Tape
CMS Lannion	Centre d'Etude de Météorologie Spatial de Lannion
COI	Co-Investigator
DIR	Day Infrared
DV	Day Visible
D	Day
EC	European Communities
EARTHNET	Section of European Space Research Institute
ESA	European Space Agency
ETP	Evapotranspiration
GMT	Greenwich Meridian Time
GSFC	Goddard Space Flight Center
GDTA	Groupement pour le Dévéloppement de la Télédét. Aérospatiale
HCMM	Heat Capacity Mapping Mission
HCMR	Heat Capacity Mapping Radiometer
HET	HCMM Experimental Team
HOM	Hotine Oblique Mercator Projection
HD	High Density
IPF	Image Processing Facility
HDT	High Density Tape
ID	Identification
IR	Infrared
IFOV	Instantaneous Field of View
IGN	Institut Géographique National
JFE	Joint Flight Experiment
JRC	Joint Research Centre
LAT	Latitude
LONG	Longitude
MSS	Multispectral Scanner

NIR	Night Infrared
NT	Negative Transparency
N	Night
NER	Noise Equivalent Radiance
ND	Night-Day
NDN	Night-Day-Night
PC	Priority Coverage
PI	Principal Investigator
PR	Progress Report
PPL	Priority Processing List
QL	Quick Look
RO	Retrospective Order
SEAL	Simplified Evaporation Algorithm
SC	Spacecraft
SO	Standard Order
TD	Temperature Difference
TI	Thermal Inertia
TNL	TELLUS Newsletter
TRK	Track
TS	Test Site
TSC	Test Site Coordinator
USWCL	U.S. Water Conservation Laboratory, Phoenix, AZ.
VIS	Visible
WG	Working Group

ANNEXES

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   May 1980.

4. TELLUS NEWSLETTER 17
   Hermann Gossmann. The influence of topographic structures on night-time surface temperatures: Evaluation of a satellite thermal image of the Upper Rhine Plain and the Surrounding Highlands.
   June 1980 (German, english summary)

5. TELLUS NEWSLETTER 18
   R. Gombeer. The comparison of HCMM-satellite registered surface temperatures with ground temperature measurements over Belgium. A calibration study.

   H. Gossmann. A calibration attempt of HCMM scene AA-0034.0213.0.3 of May 30, 1978.

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